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Published in:
Proceedings of the 14th IWA/IAHR international conference on urban drainage

Publication date:
2017

Document Version
Publisher's PDF, also known as Version of record

ICUD-0477 Using a time-lagged method to enhance Numerical Weather Prediction for urban drainage applications

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Summary

Numerical weather prediction (NWP) models are broadly available and provide prediction beyond the scope of forecasts based on radar extrapolation. The uncertainty of the NWP is expressed using Ensemble Prediction System (EPS). The fine temporal and spatial resolution required for urban applications is a challenge for the uncertainty description. The time-lagged approach utilises the previous forecasts to expand the EPS dimension and enhance its predictive skill. The forecast is assessed on both observed rain and discharge at the outlet of an urban catchment. Using the time-lagged approach increases the forecast discrimination skill by reducing missed forecast events.

Keywords

numerical weather prediction (NWP), ensemble prediction system (EPS), uncertainty, rainfall, urban hydrology

Introduction

Precipitation is the main disturbance on the operation of Integrated Urban Drainage - Wastewater Systems (IUDWS). Rainfall predictions can be used to improve the management of IUDWS. Radar extrapolation is often used to forecast flow, but the characteristic time scale for controlling IUDWS (hours to days) often lies behind the scope of the prediction from radar extrapolation (minutes to a few hours). Numerical Weather Prediction (NWP) models can provide forecasts covering this horizon and are broadly available. They are already used in many other fields, e.g. in streamflow forecasting (Shrestha et al., 2013), but can also be used at an urban scale, e.g. for pluvial flood warning or energy optimisation during dry periods. Compared to natural hydrology, finer spatial and temporal resolution is required in the urban context due to the short concentration time and the small spatial scales involved. This limitation is constantly reduced with the increase of the computational power allowing for finer NWP resolution, but fine resolutions accentuate the NWP uncertainty. The meteorological concept of "double penalty", which refers to the error resulting from a rain event correctly predicted but slightly misplaced in space and/or time illustrates this challenge. The large uncertainty embedded in NWP is commonly characterized using Ensemble Prediction Systems (EPS) generated from the perturbation of NWP initials conditions. NWP EPS tend to be under-dispersive because many verifying observations fall outside the EPS range (Feddersen, 2009). Here, post-processing methods like the time-lagged approach can be used to improve the EPS skills. The aim of this study is to evaluate the time-lagged approach to enhance (probabilistic) discharge forecasts at the outlet of an urban catchment.

Methods and Materials

This study uses the regional weather model DMI-HIRLAM-S05 (Feddersen, 2009), which generates an ensemble of 25 scenarios in a 5 km grid with hourly temporal resolution every 6 hours. A runoff model based on the Nash cascade was used to process rainfall intensity to discharge on an urban catchment. The runoff model is further described in (Courdent et al., 2016). Consecutive forecast are overlapping in time as shown in Fig. 1. The time-lagged approach utilises this overlap to expand the size of the EPS at the expense of its horizon (Mittermaier, 2007). In this study, 48 hr forecast horizon is reduced to 24 hr, which allows 4 overlaps at most.

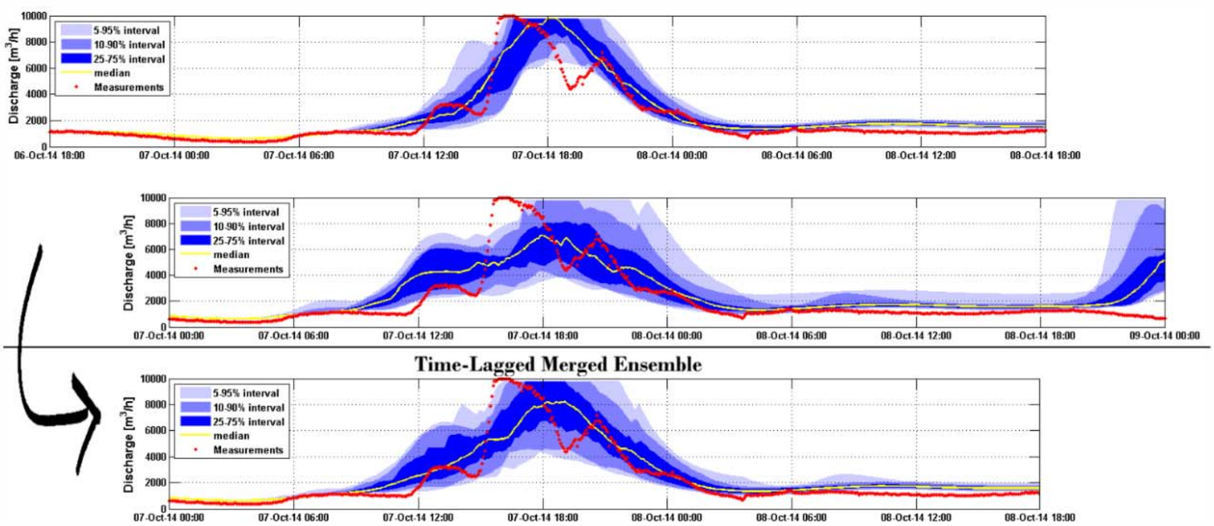

Fig. 1. *Two successive discharge forecasts (with 25 ensemble members) at the catchment outlet (top, middle) and resulting discharge forecasts (with 50 ensemble members) utilising the time-lag post processing method (bottom).*

The forecast skills are assessed using (i) the Continuous Ranked Probability Score (CRPS), and (ii) the ROC diagram which represents the discrimination skill of the EPS to prediction of an event, in this case a high flow at the outlet of catchment's drainage system (Fig. 2). The CRPS can be interpreted as a probabilistic generalization of the mean absolute error and is defined as (1).

$$CRPS = \frac{1}{n} * \sum_{i=1}^{n} \int_{-\infty}^{+\infty} \left[F_i(u) - H(u - y_i)\right]^2 du \qquad (1)$$

where H denotes the Heaviside function, F_i is the cumulative distribution, y_i the observation and n the number of forecast. Smaller CRPS values correspond to better performance.

Results and Discussion

The time-lagged approach increases the overall skill of both rain and discharge forecasts as seen in Tab. 1.

Tab. 1. *Ensemble size and CRPS (for rainfall intensity and catchment discharge forecasts) for increasing number of time-lagged overlaps.*

Time-Lags (number of overlaps)		0	1	2	3	4
EPS Size		25	50	75	100	125
CRPS	Rainfall intensity [mm/h]	0.072	0.068	0.067	0.066	0.066
	Discharge [m3/hr]	601.76	590.60	586.62	584.69	583.87

Furthermore, as showed on Fig. 2, the time-lagged approach increases the forecast discrimination (higher ROCA) increasing the scope of available probability of detection of high-flow events (in this case above 4,000 m^3/h).

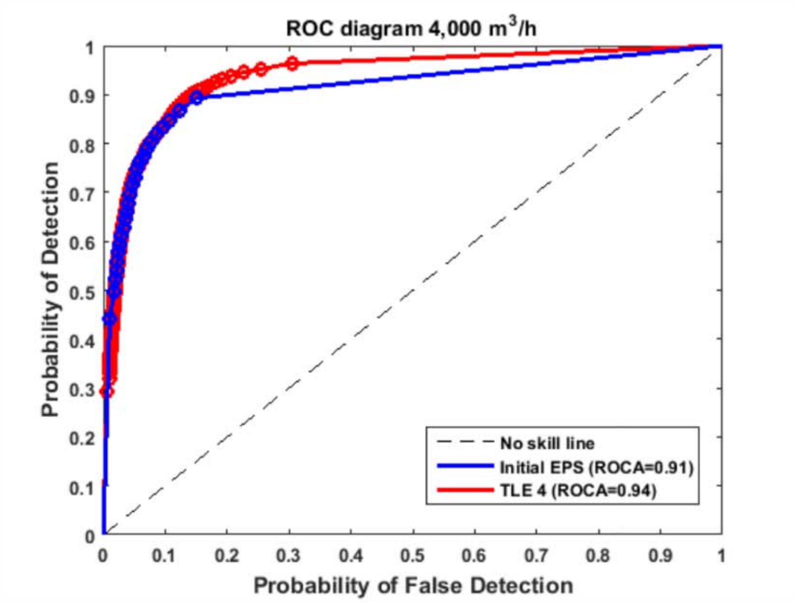

Fig. 2. *Comparison of the ROC diagrams for the initial EPS (with 25 ensemble members) and the time-lagged ensemble with 4 overlaps (and 125 members) based on discharge forecast.*

Tab. 1 shows that most of the improvement is achieved by adding the predictions from the closest previous forecast. Therefore to limit additional computational requirements of expanding the EPS, a single time-lagged forecast could be sufficient, as illustrated on Fig. 1. Further research will explore on how time-lags can be combined with other post-processing methods such as spatial neighbourhood inclusion (Courdent et al., 2016).

Conclusions

The time-lagged approach is a simple and efficient method to increase the EPS skills, providing e.g. a larger scope of probability of detection. Considering numerous overlaps is not necessary, as the largest improvement results from including the first overlap. NWPs are broadly available and can be enhanced using post-processing methods such as the time-lagged approach. Their large uncertainty limits their direct use but they can provide valuable information on weather trends for the incoming day(s).

Acknowledgement

This research was financially supported by the industrial PhD programme of the Innovation Fund Denmark. The catchment and flow data were kindly provided by Copenhagen Utility Company (HOFOR). We would like to thank the Danish Meteorological Institute (DMI), especially Henrik Feddersen, for providing the NWP data from their DMI-HIRLAM-S05 model.

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